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Helmholtz, already quoted, writes: "Whether life in Berlin is favorable to scientific pursuits may well be doubted. The teacher, it is true, gains a wider, richer field of activity, but the investigator is robbed of a larger part of his time. Kirchhoff, however, was protected by his physical disability against most of the drive of the capital, and was able to labor as he had usually done."

In his power of handling physical problems, Professor Tait ranks him as the compeer of H. L. F. Helmholtz, Stokes, Sir William Thomson, and Clerk Maxwell. His discovery of spectrum analysis is an epoch-making one in science, felt equally in the humblest chemical analysis and in the remotest star and nebula.

BALFOUR STEWART.

To have achieved a permanent place in the literature of physics is no small achievement. This honor we feel that the world will accord to Professor Balfour Stewart. He was born in Edinburgh on November 1, 1828, and died on December 18, 1887. He pursued his studies at the Universities of St. Andrews and Edinburgh. Unlike most men who have devoted themselves to science, he did not linger in the shade of university walls, but began life in a mercantile office. It is said that his leaning toward physical science first strongly manifested itself on a business voyage to Australia, thus affording another instance of the effect of solation, so characteristic of sailing voyages, upon a philosophic temperament. His first scientific papers were published in the Transactions of the Physical Society of Victoria, in 1855, at the age of twenty-seven, and were entitled "On the Adaptation of the Eye to different Rays," and "On the Influence of Gravity on the Physical Condition of the Moon's Surface." It is curious to notice that these early papers were upon the subjects which were destined to engross his attention in mature life,—the subjects of light or radiant energy in general, and the effect of gravitation potential on the physical properties of matter. Shortly after his return from Australia, he abandoned business pursuits and became the assistant of Professor Forbes. In 1858 he enunciated his extension of Prévost's Law of Exchanges, and had the good fortune to express one of the great laws of nature in so simple a manner, and with such convincing proofs from his own investigations, that the future student will always connect it with the name of Balfour Stewart. Prévost had shown that a hot iron ball, for instance, surrounded by other objects, gained or lost heat in proportion to the absorbing and radiating power of the iron and the neighboring objects. Its temperature might

remain constant if the heat it received from these objects compensated for that it lost to them. Stewart showed that radiation was not a mere surface phenomenon, — that there was a flow of heat from layer to layer of the particles of a body, — in other words, that there was a flow of heat pervading all matter, and that its direction and amount were determined by molecular conditions, — there being a complete equality between the absorbing and the radiating power of each substance. For his researches on this subject, he was awarded the Rumford Medal by the Royal Society.

In 1859 Balfour Stewart was appointed Director of the Kew Observatory, and for eleven years devoted himself to meteorology. The account of his labors in this new field can be found in the Reports of the British Association, and cover a great number of subjects, including the testing of thermometers, the perfection of self-recording apparatus for the study of the magnetism of the earth, similar apparatus for the study of atmospheric electricity, and the determination of the freezing point of mercury and the melting point of paraffine, with the subsidiary researches on the constants of the many forms of meteorological instruments.

In 1870 he was appointed Professor of Physics in Owens College, Manchester, a position which he held till his death. The character of his mind as an investigator was clearly shown by his advocacy of the laboratory method of instruction in physics. Although he was no longer in vigorous health, having been the victim of a frightful railroad accident, he did not shrink from the serious increase of labor which the laboratory method entails over the lecture and recitation method. His treatise on Practical Physics is one of the best laboratory treatises in physics, and forcibly illustrates the peculiar quality of the author's mind, which was marked by a philosophical breadth in the choice of methods to cultivate the scientific instinct.

By the publication of elementary treatises on Heat, on Practical Physics, on Elementary Physics, and on the Conservation of Energy, Stewart contributed largely to the cause of scientific education. Among these treatises, that on Heat easily takes the first place from a scientific point of view, and can be entitled a classic. It is probable that the general reader of science first gained his ideas of the great generalization of the conservation of energy from Stewart's simple exposition of the subject. He was also a frequent contributor to "Nature," and other scientific periodicals, and he wrote an article on Terrestrial Magnetism for the *Encyclopædia Britannica*. He also wrote, in conjunction with De la Rue and Loewy, a series of papers

on Solar Physics. It was natural that his labors as director of a meteorological observatory should attract his attention to even geological speculation, and we find several papers by him on Geology. In a late article in the *Philosophical Magazine*, he discusses the various theories which have been propounded to account for the magnetism of the earth, and puts forth the theory that it may be due to electrical currents circulating in the upper regions of the atmosphere, — the phenomena of the aurora being the discharge from the earth to the upper regions, or the discharge from the upper regions to the earth, — thus giving evidence of electrical currents. His paper in conjunction with Tait upon the heating of a disk of metal or ebonite by rapid rotation *in vacuo* is very suggestive in reference to the motion of heavenly bodies through space, and seems to afford color to the hypothesis of the dissipation of energy.

The closing period of his life was marked by that indulgence in peculiar physical speculations which were perhaps the outcome of a Scotch theological and philosophical environment. In "The Unseen Universe," and in the "Paradoxical Philosophy," both of which were written in conjunction with Professor Tait, we find an interesting expression of the thoughts which labors in a laboratory cannot fail to excite in a physicist's mind. The Unseen Universe is a valuable contribution to modern theological speculation, and affords the believer in miracles and the resurrection grounds for his belief, in the facts and great hypotheses of physical science. The evidence thus presented for a belief is especially interesting when compared with the historical evidences. The authors affirm, "As one result of this inquiry, we are led by strict reasoning on purely scientific grounds to the probable conclusion that a life for the unseen, through the unseen, is to be regarded as the only perfect life."

It is curious to reflect that the country which has produced a Reid and a Dugald Stewart now expresses its highest philosophical thought, not in metaphysics, but in physics. The student can find ample illustration of this in the writings of James Clerk Maxwell, of Sir William Thomson, and of Balfour Stewart.

BERNHARD STUDER.

PROFESSOR BERNHARD STUDER was born at Buren, near Bern, in August, 1794, and died at the ripe old age of ninety-three in the city of Bern, Switzerland, on the 2d of May, 1887.

He was educated as a clergyman, but never entered the ministry. After studying at the University of Göttingen, Studer became so in-